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Dynamics of kinetic arrest in a model jamming system

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1 Introduction

Jamming is a ubiquitous term typically used to refer to some form of kinetic arrest in systems with many degrees of freedom. This may be initiated by some external influence, such as a continuous shear, where it can be viewed as a limiting form of shear thickening. It can also arise spontaneously, such as an atomic or molecular glass below its glass transition which fails to reach thermodynamic equilibrium over experimental time frames. Brownian motion is not a necessary prerequisite for jamming, and indeed many non-Brownian systems such as granular media (sand, glass beads *etc.*), foams and emulsions also become arrested into a disordered solid configuration at sufficiently high densities, with or without driving. Such systems provide useful model systems for investigating the fundamental nature of the jamming transition, lacking as they do complicating factors such as aging (as long as they are not vibrated).

O'Hern *et al.* [1] employed a high dimensional optimization algorithm to minimize the potential energy of point particles interacting *via* finite-ranged, strictly repulsive, radial interactions in two and three dimensions. This efficiently generates static configurations for large systems, providing good statistics at the expense of removing all dynamical information. Various quantities such as pressure and shear modulus were found to vanish continuously at a jamming transition density with exponents that are consistent with simple rationals, independent of dimension. Further work [2] demonstrated a diverging length scale associated with normal modes as the transition is approached from above. However, the optimization algorithm is incapable of probing for a diverging time scale. Furthermore, recent work on attractive particles [3] demonstrated a sensitivity to sample preparation that has not been checked for the repulsive case.

An interactive jamming Python program demonstrating various aspects of this problem was written as part of this project; it can be freely downloaded from [4].

2 Model

Molecular dynamics simulations were performed on the same system as [1], with the addition of a viscous damping term with coefficient ν for overlapping particles, to extract kinetic energy

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from the system. The system was relaxed until all measured quantities had converged to within a predefined tolerance. See Fig. 1 for an example of a jammed configuration.

Insensitivity to damping coefficient: As shown in Fig. 1, although varying the coefficient of damping clearly alters the time dependence of measurable quantities such as the pressure, the final state is insensitive to rate of damping. It also agrees with data generated by a non-linear conjugate gradient energy minimization procedure (*not shown*). Thus sample preparation is *not* crucial for repulsive particles, in contrast to the attractive case.

Time scales around jamming: Qualitative plots of pressure versus time for differing densities (*not given*) suggest an increase in relaxation times close to the transition, both below and above. However, the statistics are currently insufficient to determine any divergence; work is ongoing to reduce error bars and extract meaningful time scales.

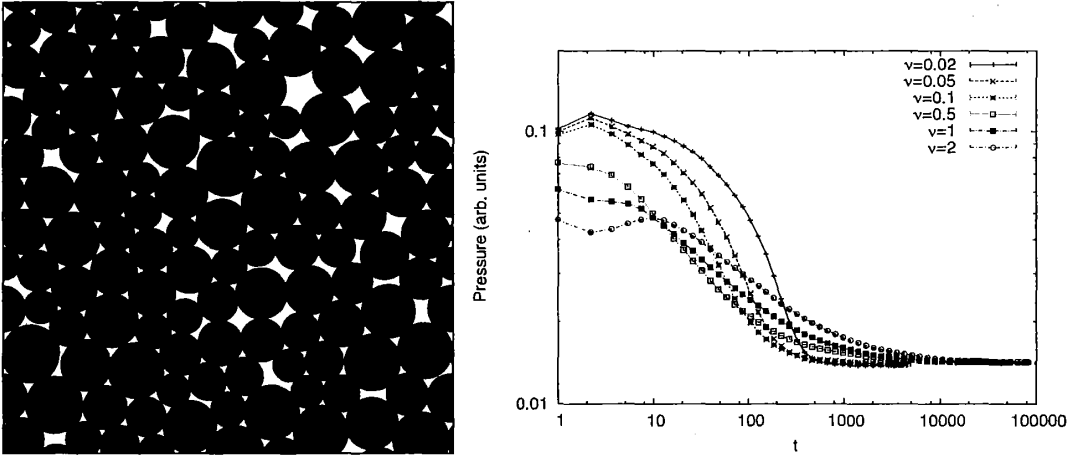


Figure 1: (*Left*) Jammed configuration just above the transition ($\phi = 0.9$ with $\phi_c \approx 0.841$ for this polydispersity). Interparticle lines are proportional to the contact force. (*Right*) Variation of pressure versus time for different damping coefficients ν .

References

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